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ECOLOGÍA

Effects of fire on the populations of ground beetles (Coleoptera, Carabidae) in an equatorial Andean páramo

Efectos del fuego en las poblaciones de escarabajos terrestres (Coleoptera, Carabidae) en un páramo andino ecuatorial

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ABSTRACT

Man-made fires are frequent during the dry season in grasslands of the páramo ecosystem of equatorial Andes, at elevations above 3400 m above sea level. They have the short-term effect of biodiversity loss and soil erosion, and the medium to long-term impact of leaving more available niches, resulting in changes in the ecosystem structure. This study aimed to understand the effects of these fires on ground beetle populations. The study area was on Cerro Atacazo where 300 ha were burned in July 2017. Samplings were made in a burned area and an adjacent unburned area at ca. 4000 m above sea level, over 17 months using pitfall trapping. Nine ground beetle species were collected, seven of which were present in the burned and unburned areas. The variations observed over time in ground beetle abundance are more likely driven by climatic factors, such as precipitation, than by the effects of fire. The species assemblages were significantly different in the two areas and no increasing pattern of similarity was observed as time passed after the fire, suggesting that reversing the effects of the fire would take more than 17 months. The response to the disturbance induced by fire appeared to be species-specific, with a greater abundance of large-size species in the burned area. Conversely, the total absence of the small-size genus *Oxytrechus* in the burned area points to this taxon as a good indicator of the undisturbed páramo environment.

Keywords: Andes, burning, Ecuador, insects, succession, tropical alpine.

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RESUMEN

Los incendios son frecuentes durante la estación seca en el ecosistema de páramo de los Andes ecuatorianos, encima de 3400 m s. n. m. Tienen efecto a corto plazo de pérdida de biodiversidad y erosión del suelo, y a mediano y largo plazo de dejar nichos disponibles, modificando la estructura del ecosistema. El objetivo del estudio fue comprender los efectos de estos incendios en las poblaciones de escarabajos terrestres. El área de estudio fue el Cerro Atacazo donde se quemaron 300 ha en 2017. Los muestreos se realizaron en un área quemada y en un área no quemada cerca de 4000 m s. n. m., durante 17 meses, usando trampas de caída. Se recolectaron nueve especies de Carabidae, siete de ellas presentes en el área quemada y no quemada. Las variaciones observadas a lo largo del tiempo en la abundancia de las especies probablemente se deban más a factores climáticos, como precipitación, que a efectos del fuego. Los conjuntos de especies fueron diferentes en las dos áreas y no se observó un patrón creciente de similitud a medida que pasaba el tiempo después del incendio, sugiriendo que la anulación de los efectos del fuego toma más de 17 meses. La respuesta a la perturbación ocasionada pareció ser propia de cada especie, con mayor abundancia de especies de gran tamaño en el área quemada. La ausencia del género *Oxytrechus*, de tamaño pequeño, en el área quemada hace de este taxón un buen indicador de un ambiente de páramo no perturbado.

Palabras clave: Andes, Ecuador, insectos, fuego, sucesión, páramo.

INTRODUCTION

The páramo ecosystem which is found in the tropical Andes above the tree line, from 3500 m above sea level to the snow line (Luteyn *et al.* 1999, Mena *et al.* 2000, Ministerio del Ambiente del Ecuador 2012) is fundamental to the regulation of water resources and conservation of a large number of endemic animals and plants (Mena Vásconez *et al.* 2011, Vargas-Ríos 2013, Rivadeneira *et al.* 2020). During the dry season, this ecosystem is prone to disturbances caused by fire (Williamson *et al.* 1986, Vargas-Ríos 2013). Their main causes are intentional burns to obtain new grass for animals or to convert the grasslands into fields and forests (Vargas-Ríos 1997, 2013, Borrelli *et al.* 2015). Dry vegetation becomes a fuel that generates high-intensity fires, which with the help of easterly winds can spread uncontrollably over large areas (Vargas-Ríos 2013, Armenteras *et al.* 2020). The after-effects of fire are large changes in the physical, chemical, and biological properties of the ecosystem (Beltrán Pineda and Lizarazo-Forero 2013, Kacprzyk *et al.* 2020). Among the biological impacts are: the total or partial destruction of vegetation, the death or displacement of animals, and the availability of new habitats, or new niches, for recolonization (Vargas-Ríos 2013, Ruchin *et al.* 2019, Armenteras *et al.* 2020).

Páramo vegetation, having not evolved under a continuous regime of disturbances, has not developed high thresholds of resistance and resilience to fire (Vargas-Ríos 2013). The pajonal, or grassland zone of the páramo, is dominated by grasses of the genera *Calamagrostis* Adans. and *Festuca* L. (Ramsay and Oxley 1996, Vargas-Ríos 2013). Generally, in a páramo fire, the grassland facilitates the combustion and the expansion of the fire, but the dry straw also protects the meristems of the plants and does not allow the fire to reach the soil surface (Ramsay and Oxley 1996, Vargas-Ríos 2013). With land use change for agriculture and animal grazing, fires have increased in frequency, which in turn has increased the length of the vegetation recovery period after a fire, which lasts at least five years on average (Ramsay and Oxley 1996, Vargas-Ríos 2013).

The studies carried out to date have focused on the impact of fires on the vegetation of the páramo, rarely on the arthropod soil fauna (Pickett 2001). Within the latter, one of the taxonomic groups most used as bioindicators to evaluate changes and disturbances in ecosystems is the family Carabidae, also called ground beetles (Holliday 1992, Rainio and Niemelä 2003, Gobbi *et al.* 2018), for their diversity, sensitivity to environmental changes, and the low cost of requested fieldwork. In addition, Carabidae is one of the most numerous Coleoptera families living in the páramo, as far as species richness is concerned (Martínez and Ball 2003, Moret 2005). The diversity of Carabidae in the mountains of Ecuador has been thoroughly studied and there is extensive knowledge of the taxonomy of this group. As of 2005, 204 species were known to live in the páramos of Ecuador (Moret 2005), and recently 25 more species have been described using molecular techniques (Moret and Murienne 2020).

In temperate (boreal) zones, several studies on the effects of habitat disturbances caused by fire were based on ground beetles, by comparing the populations between areas affected by fire and control areas. Most of the researchers found that the greatest diversity and abundance was in the areas disturbed by fire, which is explained by the fact that fires create new niches available to be colonized, while competition remains low. For these reasons, new species arriving in the burned area find sufficient resources to increase their populations (Halme and Niemelä 1993, Gandhi *et al.* 2001, Fernández Fernández and Salgado Costas 2004, Huber and Baumgarten 2005, Martikainen *et al.* 2006, Cobb *et al.* 2007, Ruchin *et al.* 2019). However, other studies have yielded different results. In one of them, it was found that there were no differences in community composition between control and burned areas (Kacprzyk *et al.* 2020), and according to others, there was greater abundance and species richness in the control non-disturbed area (Holliday 1992, Verble-Pearson and Yanoviak 2014). These variations may be related to the time when the sampling was performed: if it was soon after the fire, there may have not been enough time for new species to colonize the impacted area. Another variable that also plays a particularly important role is the intensity of the fire: if it is very intense it destroys all the previously existing entomofauna and leaves room for new species to colonize the place without competition. On the other hand, if it is not intense, most of the plant and insect communities survive, protected by the leaf litter and the superficial layer of humus, later becoming competitors for the new colonizing species. Finally, in a study limited to the area disturbed by fire in a forest in Sweden, without a control area, it has been shown that the post-fire ecological succession was dominated by specialized pyrophilic species (Gongalsky *et al.* 2003).

The objective of this study was to document the effects of fire on populations of ground beetles of the Carabidae family in a páramo of the tropical Andes and to obtain information on how diversity and abundance change over time after the fire, comparing it to a control population from a neighboring area that did not burn.

MATERIAL AND METHODS

Study area

Cerro Atacazo is an extinct volcano located on the western cordillera, close to the Metropolitan District of Quito (Fig. 1). Its summit reaches 4455 m above sea level. In July 2017, a fire consumed around 300 hectares of its northern slope (El Comercio c2017). The sampling was carried out in this sector at around 4000 m above sea level. in a burned area (BA) (0° 20'34.63" South, 78° 37'05.77" West) and in an unburned area (UBA) (0° 20'37.65" South, 78° 37'06.05" West). These areas were separated by a path, which functioned as a firewall.

Sampling of Carabidae

The investigation began three weeks after the fire, in August 2017, and lasted until January 2019. Five sampling sessions were carried out: (1) in month one after the fire, from 15 Aug 2017 to 18 Sep 2017; (2) in month four after the fire, from 20 Nov 2017 to 19 Dec 2017; (3) in month nine after the fire, from 24 Apr 2018 to 22 May 2018; (4) in month thirteen after the fire, from 22 Aug 2018 to 19 Sep 2018; (5) in month 17 after the fire, from 12 Dec 2018 to 9 Jan 2019. During each sampling session, the traps were collected, recorded, and recharged four times, at fifteen-day intervals. To collect the insects, twelve pitfall traps were used (7 cm diameter plastic cups, filled up to 2/3 with natural vinegar and salt), in the burned area as well as in the unburned area, six traps were placed every 10 m along a 50 m straight line. This is a standard protocol when using pitfall traps to collect ground beetles (Gobbi *et al.* 2018).

Sampling was done in the rainy season (April-May) and the dry season (August-September), as well as in intermediate seasons (November-January). The identification of Carabidae was completed following the taxonomic keys for Carabidae from the páramos of Ecuador (Moret 2005). The results of each trap were recorded separately, except in session 1, in which only the sum of the individuals collected in all the traps in each area was recorded. For this reason, the results of session one was not included in the statistical analysis.

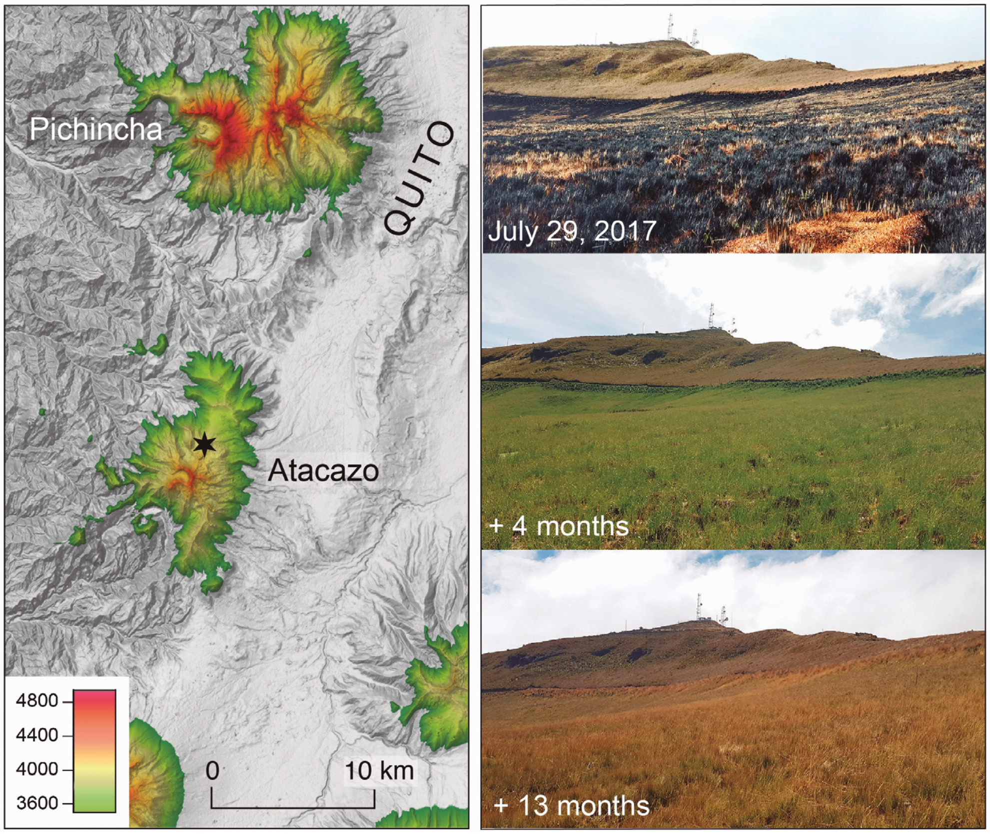

Figure 1. Study area (marked with a star). Sequence of photographs of the disturbed area at three weeks, four months, and thirteen months after the fire.

Meteorological data

The closest meteorological station is the "Guamaní" station (78° 33' 5" West, 0° 19' 51" South), located at 3066 m above sea level, only 6.7 km east of the study area. The biweekly rainfall data from this station during the entire sampling period were extracted from the online files of the Secretary of the Environment of the Municipality of the Metropolitan District of Quito (Secretaria de Ambiente DMQ c2020).

Statistical analysis

To determine if the sampling effort was adequate, samples two to five (the only ones with complete data) were used to calculate the species accumulation curve and the true species richness estimated for each sample/day with the estimation of Chao 2 using the computer program EstimateS (Colwell c2005).

The number of species and abundance of individuals was calculated for each trap. We also estimated richness at the transect scale to compare the total number of species potentially found on each sampling date. When considering the traps as independent units, we were aware that the analysis could suffer from pseudo-replication (Hurlbert 1984). However, great differences were recorded in species assemblages from neighboring traps, in line with a previously observed small-scale heterogeneity in the spatial distribution of Carabidae (Niemela *et al.* 1992).

A Wilcoxon Test and a T-Test were used for independent samples to determine if there were differences between the means of abundance and richness in the burned area versus the unburned area, for samples two to five.

Non-metric multidimensional scaling (NMDS) was performed to analyze the biological similarity patterns in the communities present at the study site in the burned and unburned areas (Gucht *et al.* 2005). The Bray-Curtis method was used as a measure of similarity. Samples from the same area were grouped with convex hulls.

The goodness of fit of the NMDS was estimated with a stress function (ranging from zero to one), with values close to zero indicating a good fit. The difference in community composition between BA and UBA areas was tested using an analysis of similarities (ANOSIM). This method has been previously used to test hypotheses about spatial differences in plant and animal communities (Chapman and Underwood 1999).

ANOSIM tested the null hypothesis that the similarity within the sites was equal to the similarity between the sites. ANOSIM generates a statistical R parameter that is indicative of the degree of separation between groups; a value of one indicates complete separation and a value of zero indicates that there is no separation (Gucht *et al.* 2005). Monte-Carlo randomization was used to generate null distributions to test the hypothesis that the similarities within the group were higher than would be expected by chance alone. All analyses were performed using PAST (Paleontological Statistics, version 3.25). Abundance data was transformed with Ln (X + 1), which is commonly applied to invertebrate data to reduce the importance of outliers caused by occasionally large values of high abundance (Clarke 1993).

RESULTS

Nine species of Carabidae were collected in the five sampling periods, amounting to a total of 1990 individuals (Table 1). The species number falls within the diversity range of this beetle family, at the local scale, in the grassland páramos of the Western Cordillera of the equatorial Andes, which fluctuates locally between seven and fifteen species (Moret 2005).

The most abundant species was *Dyscolus denigratus* (Bates, 1891) with 1595 individuals, being the dominant species with around 80.2 % of the total individuals in the study. *Blennidus mucronatus* (Moret, 1996) and *Bembidion fulvocinctum* (Bates, 1891) were the second most abundant species, representing 7.3 % each. *Pelmatellus columbianus* (Reiche, 1843) and *Oxytrechus* sp. were the rarest, with around 0.5 % of the total number of individuals. Seven species were found in both the BA and the UBA, while the two rarest species, *P. columbianus*, and *Oxytrechus* sp., only appeared in one area: the first in the BA, the second in the UBA (Table 1).

Abundance

The Wilcoxon Test for abundance indicated a difference between the two areas sampled during the second sample period (*P* value = 0.039), with a much higher number of individuals in the BA (408) than in the UB (243). On the contrary, in the third, fourth, and fifth samples, this analysis did not indicate significant differences in the abundances between the burned and unburned areas ($P \geq 0.05$).

Table 1. Species found in the five sample periods, with their respective abundance, separated by burned (BA) and unburned areas (UBA), and the total sum of individuals found.

	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5		TOTAL
	BA	UBA	BA	UBA	BA	UBA	BA	UBA	BA	UBA	
Bembidion fulvocinctum	0	18	1	46	1	49	0	15	1	15	146
Blennidus mucronatus	9	0	29	16	11	19	4	3	29	25	145
Blennidus strictibasis	0	0	0	0	1	3	1	0	0	1	6
Dercylus cordicollis	1	0	14	2	2	2	0	0	10	4	35
Dyscolus alpinus	0	0	11	0	0	0	2	0	1	2	16
Dyscolus denigratus	34	38	351	164	100	104	118	30	379	277	1595
Dyscolus verecundus	0	0	0	11	0	3	0	1	1	13	29
Oxytrechus sp.	0	0	0	4	0	3	0	1	0	0	8
Pelmatellus columbianus	3	0	2	0	4	0	1	0	0	0	10
	47	56	408	243	119	183	126	50	421	337	1990

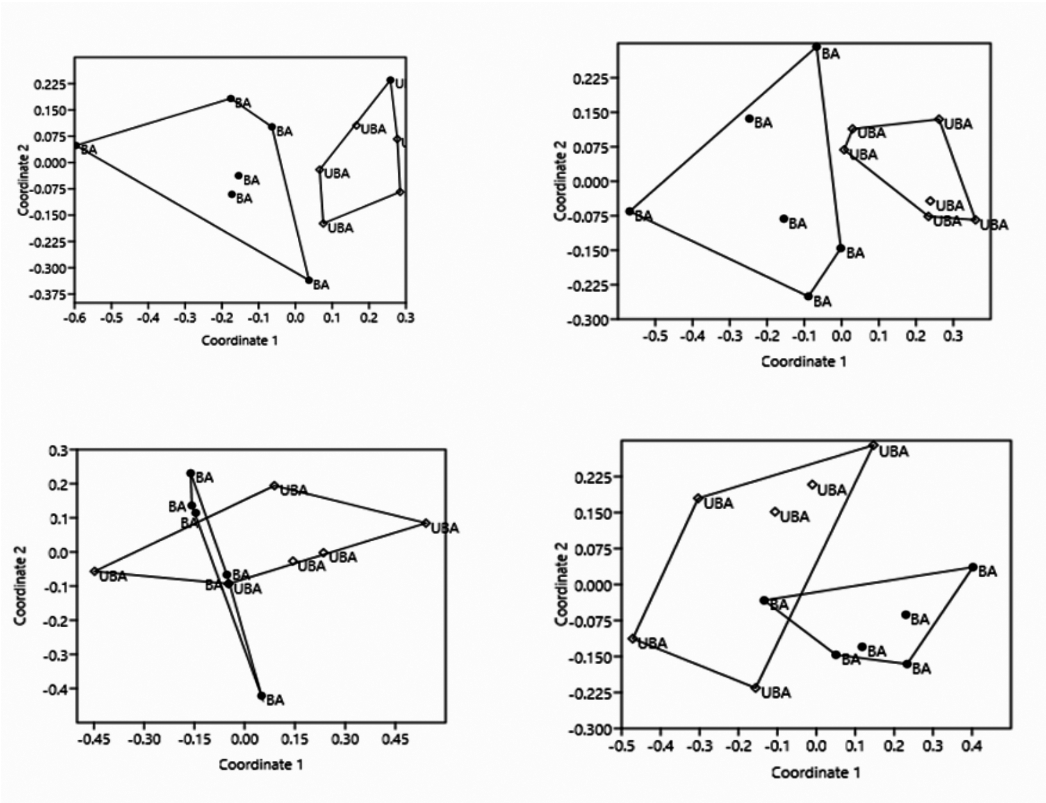

Figure 2. NMDS (Bray-Curtis) for the abundance of Carabidae in the burned and unburned area, in four sampling periods; a. Sample 2, b. Sample 3, c. Sample 4, d. Sample 5.

(Fig. 2) shows the ANOSIM (Bray-Curtis) graphs for Carabidae abundance. In the second sample (Fig. 2a) values were R = 0.4556 and P = 0.0022, which shows that the communities are distinct. In the third sample (Fig. 2b) values were R = 0.5389 and P = 0.0042, which indicates that the communities are also distinct. In the fourth (Fig. 2c) values were R = 0.1796 and P = 0.0539, indicating that the communities were beginning to resemble each other. In the fifth sample (Fig. 2d) values were R = 0.4019 and P = 0.0125, indicating that the communities were again distinct.

In both areas, the total abundance reached its maximum in samples two and five, i.e., in November-December, and had its minimum in samples one and four, in August–September (Table 1). Comparing these trends, which are identical in 2017 and 2018, with the precipitation curve from the closest weather station (Fig. 3), it appears that the highest abundance of Carabidae is found after a short period of high precipitation (>100 mm in fifteen days) in October or November. This pattern is not repeated when rainfall remains high for a longer period: sample three, which corresponds to the April–May wet season with more than 400 mm of rain in two months, showed relatively low abundance. The lowest abundance was observed repeatedly in August, at the end of the dry season, after two months of very low amounts of precipitation.

Species richness

The richness observed varied between four and eight species in the BA and between two and seven in the UBA (Table 1). The Chao 2 accumulation curves (Fig. 4) show that the sampling effort displayed in the second, third, and fourth samplings was sufficient to capture the existing diversity in the two areas. Only in the fifth sample period (Fig. 4d) we found that the effort was insufficient since the curve does not stabilize in the BA.

The T-Test for species richness only resulted in a significant difference between the two areas sampled for the second

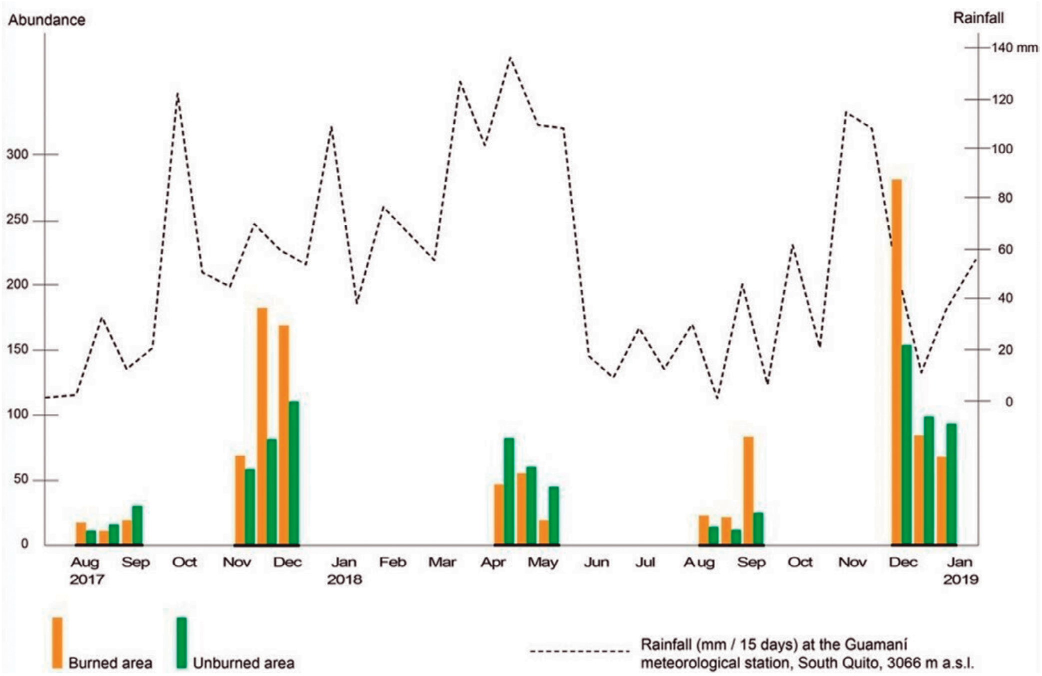

Figure 3. Abundance of Carabidae in the five sample periods, distinguishing the three sessions of each sampling (vertical bars), compared with the fortnightly average of precipitation (dashed line, in mm) at the "Guamaní" meteorological station, 6.7 km east of the study area

sample (P = 0.007); in the third, fourth, and fifth sample periods there are no significant differences between the BA and the UBA ($P \geq 0.05$).

In (Fig. 5) we can graphically observe the ANOSIM (Bray-Curtis) for the species richness data. In the second sample (Fig. 5a) R = 0.4398 and P = 0.006, indicating that the communities are distinct, in congruence with the T-Test. In the third sample (Fig. 5b), there R = 0.3583 and P = 0.0066, which indicates that the community is more similar than in the previous period. In the fourth (Fig. 5c), R = 0.2204 and P = 0.0529, indicating increased similarity between the communities. On the other hand, in the fifth sample (Fig. 5d) R = 0.4324 and P = 0.0166, suggesting that the communities are again distinct.

DISCUSSION

Studies on the effects of fire on arthropod communities have shown that assemblages are affected first by the mortality caused by this disturbance, then by the arrival of species adapted to disturbances and habitat succession, which alters the community structure (Holliday 1992, Cobb *et al.* 2007, Verble-Pearson and Yanoviak 2014). In temperate regions, most studies point to a greater abundance and richness in the BA compared to the UBA, and a different composition of the Carabidae communities in the two areas (Gandhi *et al.* 2001, Gongalsky *et al.* 2003, Fernández Fernández and Salgado Costas 2004, Martikainen *et al.* 2006, Cobb *et al.* 2007, Ruchin *et al.* 2019). In two studies conducted shortly after the fire, the opposite occurred, with higher abundance and species richness in the UBA, compared to BA (Holliday 1992, Verble-Pearson and Yanoviak 2014). These studies suggest that high-intensity fire destroys the local arthropod fauna, and early sampling may show that the process of recolonization of both plant and animal species has not yet occurred.

In our study, no clear pattern was observed in the succession of ground beetle assemblages in BA and UBA. Their similarity did not increase, neither in richness nor in abundance, as time passed after the fire. A similar result in a forest in Poland (Kacprzyk *et al.* 2020) was related to a low-intensity fire which allowed many taxa to hide under the ground, or find patches with high humidity or other shelters, and thus survive (Verble-Pearson and Yanoviak 2014). In the páramo, the impact of fires is buffered by the large amount of dry grasses that accumulate at the base of the vegetation cover, protecting from the flames the meristems, the litter, and part of the soil fauna (Ramsay and Oxley 1996). The fire, as it does not directly reach the ground, does not drastically affect the fauna of Collembola and other soil arthropods that are preyed by Carabidae

(Gongalsky *et al.* 2003). This could explain why, in our study, all species but two were found both in BA and UBA, with similar abundances.

Surprisingly, in the first sampling period that was carried out shortly after the fire (Table 1), the diversity was greater in the BA (four species) than in the UBA (two species). In the UBA, the very low diversity of the first sample could be explained by the time of year, at the end of the dry season, which negatively impacts the activity of ground beetles. In the BA, due to the lack of data before the burning, it is impossible to know which factor had the greatest effect, the seasonal dryness or the fire. However, the higher diversity recorded at that time in the BA suggests that pioneer species were attracted by the perturbed area very soon after the fire. In both areas, as soon as humidity increased when the dry season was over, an increase in richness and abundance was recorded in the following samplings, as observed in another study (Castañeda Córdova *et al.* 2007).

During the whole study period, we have found a close relationship between abundance and rainfall in both areas (Fig. 3). It appears that increased precipitation and the consequent increase in humidity favors the activity of the adult ground beetles, which fall in greater numbers in the pitfall traps. However, it was also observed that during a long period of rain, such as the one that usually occurs between March and May (third sampling session),

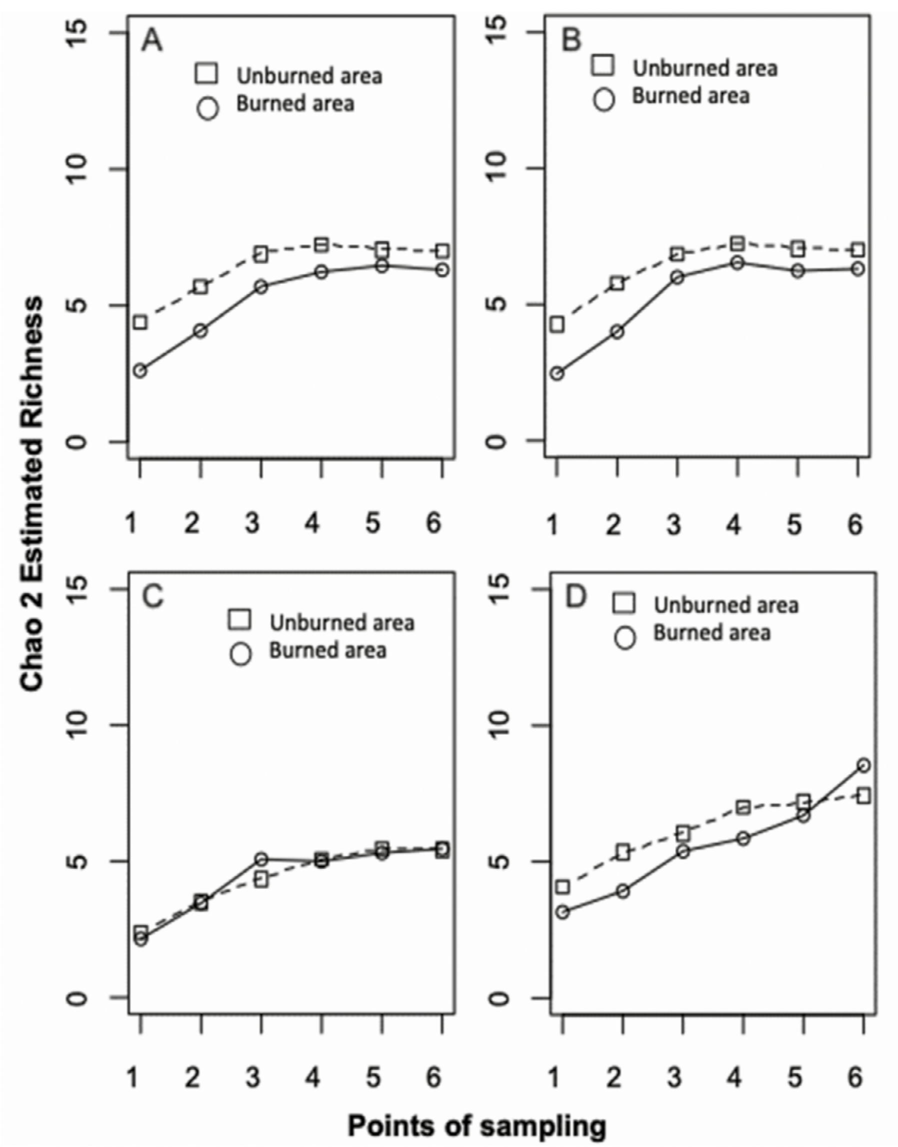

Figure 4. Chao 2 accumulation curves for estimating species richness for each sampling area in four sampling sessions. a. Sample 2, b. Sample 3, c. Sample 4, d. Sample 5. Catch units express the total sampling effort at a site. Each curve represents 500 randomizations using the EstimateS program.

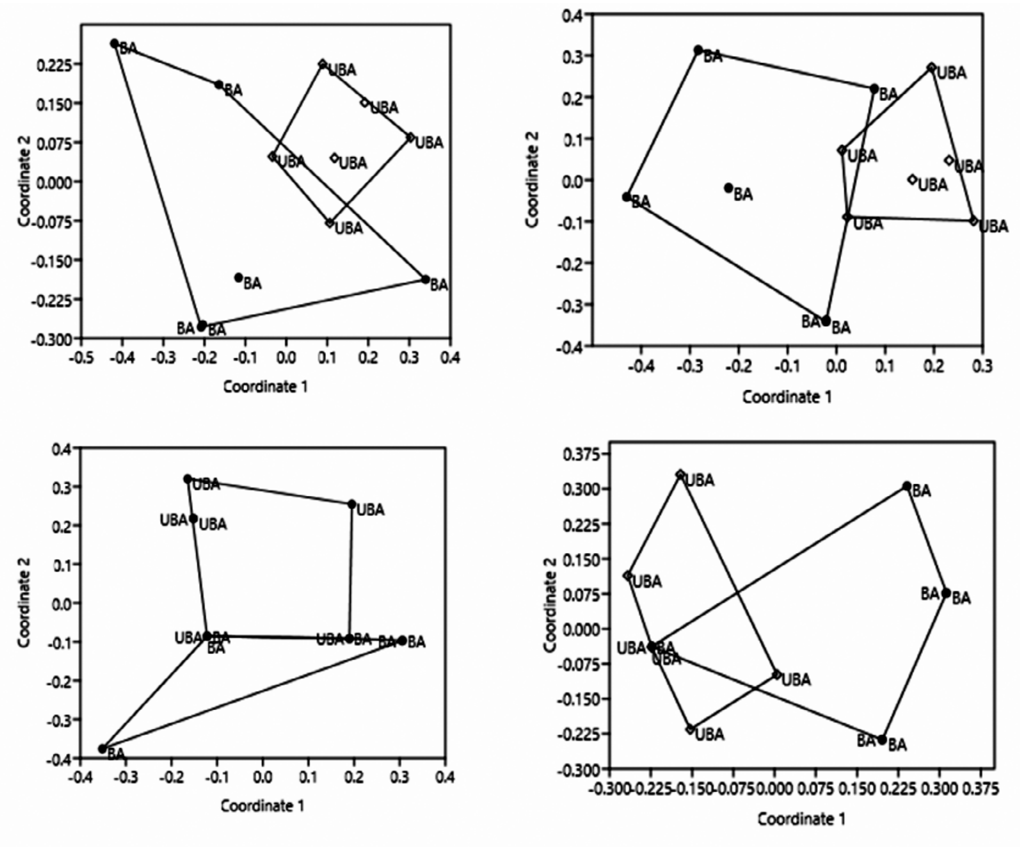

Figure 5. NMDS (Bray-Curtis) of Carabidae richness in four sample periods; a. Sample 2, b. Sample 3, c. Sample 4, d. Sample 5.

the abundance declines again. Little is known about the capabilities of páramo Carabidae in terms of tolerance to moisture and dryness, but they have been shown to have a relatively high rate of body water loss under dry experimental conditions (Somme 1989). This low resistance to desiccation forces them, during dry periods, to seek refuge most of the day in microbiotopes that maintain high and stable humidity (Moret 2005), which reduces their mobility and, therefore, the chance of falling into pitfall traps. However, this factor does not explain the relatively low abundance observed in the third sampling session in the middle of the rainy season. More studies will be necessary to clarify the relationship between abundance and humidity, but the environmental conditions with alternating dry and humid periods seem to have had a strong impact on the abundance of Carabidae in the burned area, potentially superior to post-fire succession dynamics.

In this study, *Dyscolus denigratus* was the dominant species with the highest numbers of collected individuals, both in the BA and UBA areas. The abundance of this species demonstrates that it is not sensitive to disturbances and that it is indifferent to the state of the soil. It is a generalist species, common in anthropized areas of the low páramo, such as pastures or roadsides (Moret 2005).

Pelmatellus columbianus is the only species that was exclusively found in the BA, without any record in the UBA. It is a very common species both in the high Andean montane forest and the transition zone towards the páramo. With a broad ecological tolerance, it is a synanthropic species that is present in fragmented habitats and fields of the Andean highlands (Moret 2001, Muñoz-Tobar 2019). In Peru, it is known as a biological control agent within agricultural systems because it feeds on phytophagous insects in potato fields (Kroschel and Cañedo 2009). In the same study, *P. columbianus* also demonstrated resistance to insecticides. Moreover, stubble burning is often carried out in agricultural areas where it thrives. All these characteristics help to understand its presence in the BA as a pioneer species adapted to disturbed habitats. Its low abundance is probably due to the fact that the height of 4000 m is very close to its physiological limit, as its range of highest abundance is between 2000 and 3500 m above sea level (Moret 2005).

Two species, *Dyscolus alpinus* and *Dercylus cordicollis*, also show a clear preference for the burned area, with an abundance between four and seven times greater than in the unburned area and with a higher number of individuals in the first sampling session after the fire (Table 1). They are also known to be pioneer species, typical of ecotone areas between the forest and the páramo and with a wide distribution in northern Ecuador (Moret 2005, Muñoz-Tobar 2019).

On the contrary, *Oxytrechus* sp. was found only in the unburned area, which may be related to its habitat preference. Representatives of this genus, all very small (between 2.5 and 3.2 mm), are most frequently found by sifting litter, both in the upper montane forest and in the paramo (Allegro *et al.* 2008, Giachino *et al.* 2014, Moret and Faille 2024). Due to their tiny size, they are prone to hide at the base of plants in clumps of organic matter, which might explain why this genus was only found in the UBA. The presence of *Oxytrechus* could therefore be used as a bioindicator of areas that have not been subject to disturbances in recent years. Moreover, *Oxytrechus* species are markedly hygrophilous, with a greater diversity in the humid páramos of the eastern Cordillera (Moret and Faille 2024), which may be another reason for their absence in a burned area, as has been observed with hygrophilous species in other studies (Holliday 1992, Fernández Fernández and Salgado Costas 2004).

In the BA, we observed a greater abundance of the larger species (body length between 8 and 12 mm: *D. alpinus*, *D. denigratus*, *D. cordicollis*), and a very low abundance (*B. fulvocinctum*) or total absence (*Oxytrechus* sp.) of the two smallest species (body length between 2.5 and 4.5 mm). This trend could be explained by the greater dispersal capacity of large species, which due to their size, are capable of crossing greater distances during the period of nocturnal activity which is the rule for all Carabidae in the páramo (Moret 2005). Therefore, these large species could have arrived first in the process of recolonization of the burned areas. However, there is no trend towards the arrival of more individuals of the small species as time progresses after burning, which makes this hypothesis weak. Another possible explanation would be that small species could be more dependent on certain conditions of humidity or biogeochemical equilibrium within the litter layer, conditions that would be altered for at least one year and a half after burning, even though the fire has not destroyed the upper organic layer of the soil.

In conclusion, trends in abundance and species richness did not present a clear pattern in the short term after burning, since during the 17 months of the study the similarity between the two areas did not increase, and each area presented a different community structure. These results are in line with the observation that the total recovery of a plant community in a burned grassland in the páramos of Ecuador occurs at least five years after a fire (Ramsay and Oxley 1996). The vegetation succession after a fire is characterized in the first year by the arrival of grasses and small, creeping plants that recolonize the area; after two to three years, low, medium, and tall shrubs begin to sprout again (Vargas-Ríos 1997). These data suggest that the burned area under study still faced a long process of succession before reaching maturity. Hand in hand with the regeneration of the vegetation cover goes the entomofauna (Holliday 1992). This demonstrates the need to continue sampling annually in the medium or long term, to determine how long it takes for a páramo ground beetle community to wholly recover after a fire.

AUTHOR'S CONTRIBUTIONS

WP writing original draft, data curation, methodology, CC data analysis, methodology, writing - review and editing, PM writing original draft, data curation, methodology, AB writing original draft, methodology, project administration.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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